BEALE STREET & WOLLASTON CENTER DRAINAGE STUDY

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EXECUTIVE SUMMARY

The City of Quincy Department of Public Works (DPW) has embarked on a city-wide drainage modeling program focused on Quincy's major drainage basins to systematically analyze the City's existing drainage infrastructure. This Report pertains to the specific Beale Street & Wollaston Center focus area within the Wollaston Center Subbasin of the Quincy Bay Drainage Basin. The specific focus area has been identified as a priority in the City's 2019 Drainage Assessment and Capital Plan Report (Capital Plan). This study evaluates the existing flooding conditions and capacity of the municipal drainage system in the Wollaston Center Subbasin. The goal of this study is to ascertain the cause of flooding issues experienced. Future infrastructure improvements that may be necessary to facilitate redevelopment of the Wollaston Center neighborhood will be developed in a future phase of the project.

Please note, other priority areas identified in the Capital Plan are subject to future modeling efforts.

1. INTRODUCTION

The purpose of this study is to identify potential causes for flooding observed in the roadways and adjacent public and private properties of the Beale Street & Wollaston Center focus area (focus area). To perform the evaluation, a hydraulic model was developed for the Wollaston Center Subbasin (subbasin), encompassing the focus area and its contributing drainage area. This report summarizes the model development methodology, assumptions and model results. Model results include an evaluation of locations with conveyance deficiencies and the flood risks to infrastructure and private properties. A future phase of the project will discuss an alternatives analysis of potential improvements to mitigate hydraulic deficiencies and surface flooding within the focus area.

2. MODEL DEVELOPMENT

The hydraulic model was developed using InfoWorks ICM™ version 10.0 (InfoWorks) software by Innovyze. InfoWorks provides a fully-dynamic solution for modeling one-dimensional (1D) sanitary and storm sewer systems using the St. Venant equations, and can integrate a two-dimensional (2D) surface model for estimating rain-on-grid hydrology, infiltration on pervious surfaces, and overland flow. Due to the complexity of flow in the area, and the better precision provided by the 2D mesh which uses a physics-based solution based on distributed hydrologic information, the model developed for this focus area includes both 2D and 1D components.

2.1 Focus Area

The Beale Street & Wollaston Center neighborhood is located in the northwestern section of the City of Quincy. Hydrologically, the focus area is located midway through the Wollaston Center Subbasin, in the western portion of the Quincy Bay Basin (see **Figure 1**). The subbasin's contributing drainage network discharges into Quincy Bay through the mapped drainage outfall identification number OF-00871. There is an existing flapper-style tide gate along this drainage trunk line, located in the Ocean Cove Condominium complex parking lot on the inland side of Quincy Shore Drive. This tide gate has been accounted for within the model. Note, there is a pipe network accounted for in the subbasin that flows north to south contributing to the OF-00871 watershed, flowing gravity through a historic drain force main. **Table 1** summarizes characteristics of the modeled subbasin, which has been defined to include all areas that drain to OF-00871.

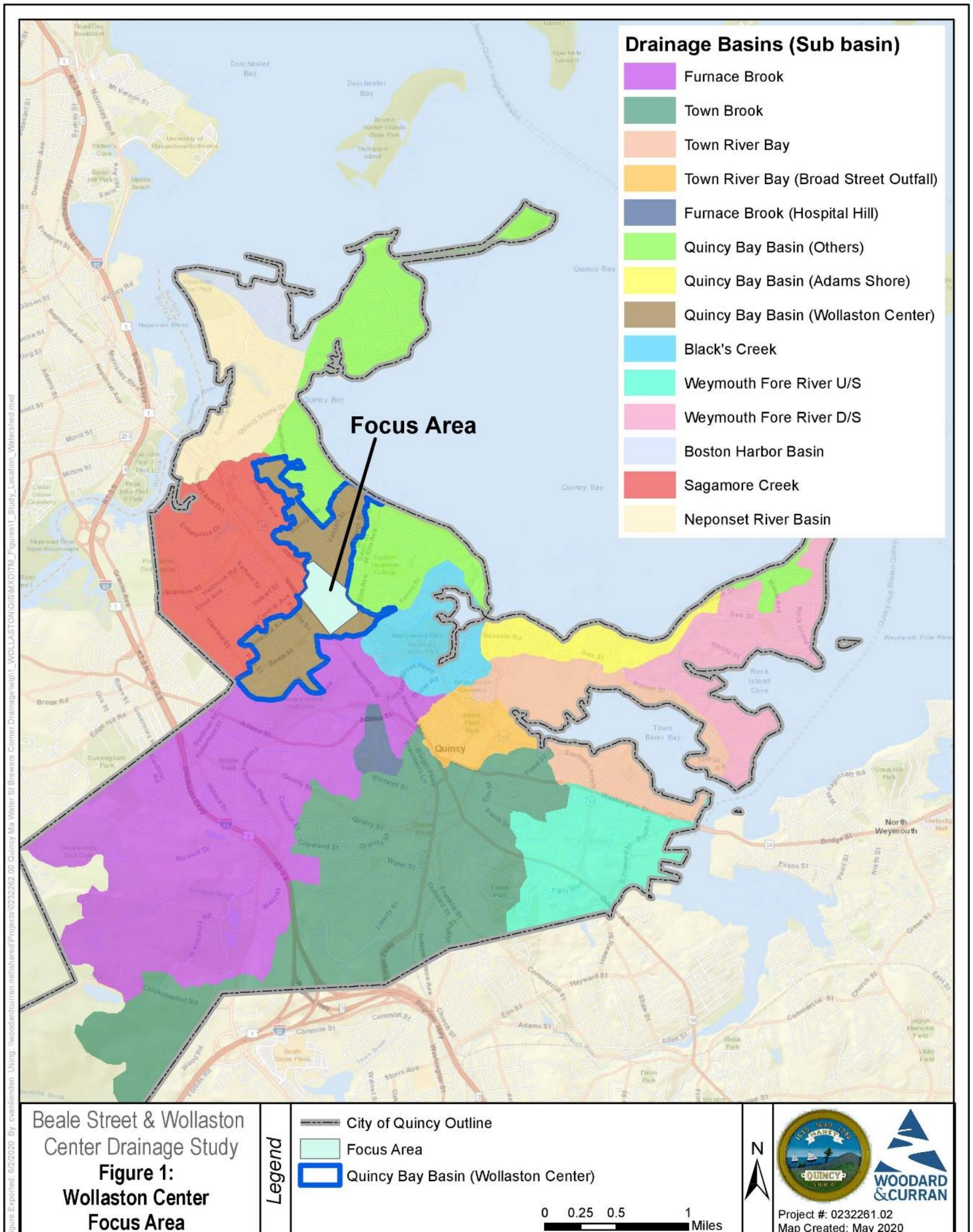
Table 1: Modeled Subbasin Characteristics

	Modeled Drainage Area
Area (acres)	450
Approximate Upstream End	Furnace Brook Golf Club
Approximate Downstream End	Quincy Bay
Primary Land Uses	Urbanized with Deciduous Forest
Impervious Cover (%)	64
Elevation Range (NAVD88 ft)	Roughly 0 to 180

For modeling purposes, the InfoWorks model includes a conservatively sized buffer around the actual expected drainage area to ensure that all potential inflows are accounted for. This is represented as the Modeled 2D Extent in **Figure 2**. While 2D overland flow was represented across an expanded area, the stormwater pipe network was represented within the InfoWorks model if it drained into the Beale Street & Wollaston Center focus area and discharged through outfall OF-00871 (outlined in **Figure 2**). This focus area was determined based on discussions with the City of Quincy Planning and Community Development Department in an effort to understand future infrastructure improvements that may be necessary to facilitate redevelopment of the Wollaston Center neighborhood.

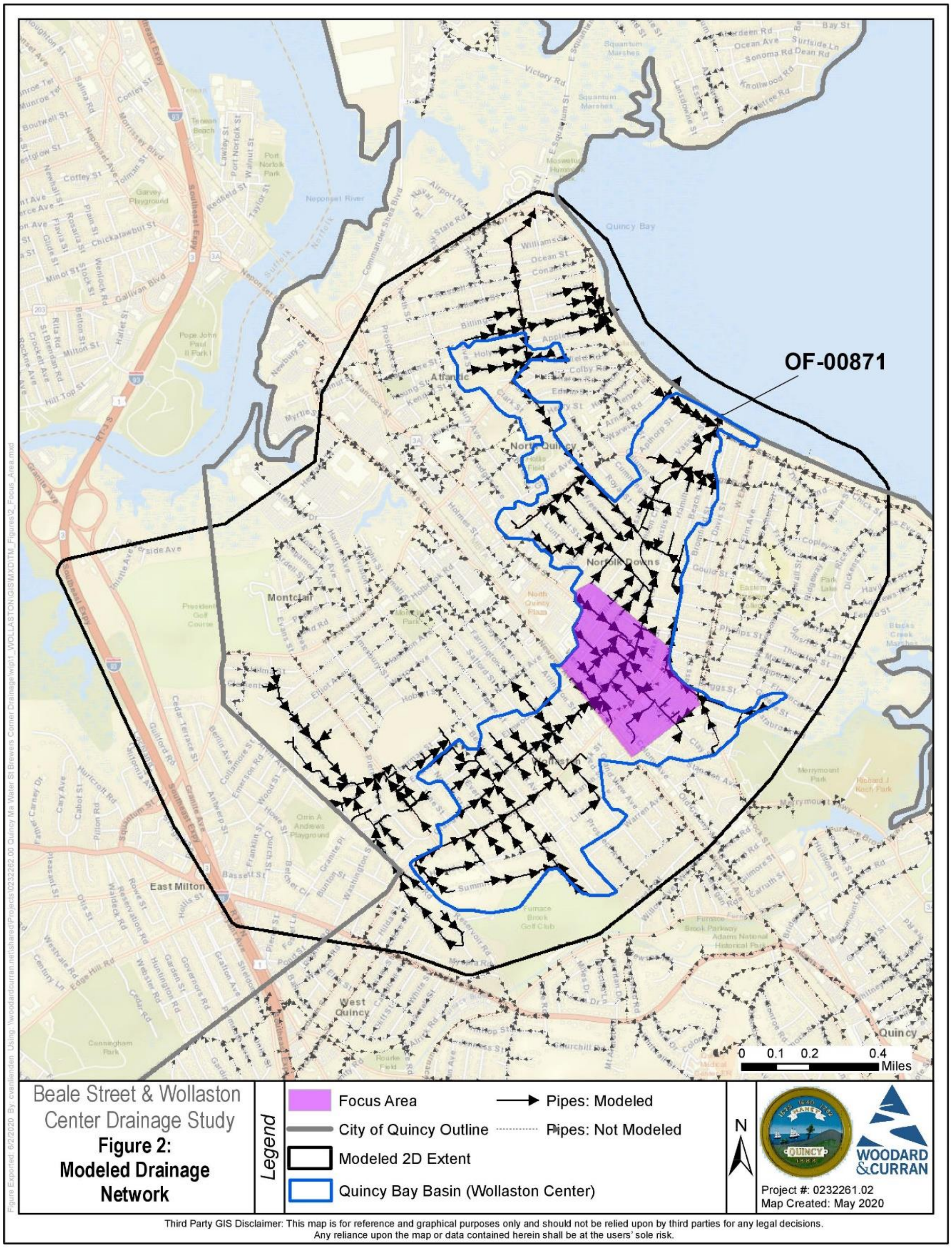
The modeled area has a single boundary condition at its downstream end to represent storm tide from Quincy Bay. This boundary condition will be discussed in later sections of this report.

Figure 1: Beale Street & Wollaston Center Focus Area



Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk.

Figure 2: Modeled Drainage Network



2.2 Horizontal and Vertical Datums

The horizontal projection used for this project is the North American Datum (NAD) 1983 State Plane Massachusetts Mainland FIPS 2001 Feet.

The vertical datum used for model development is the NAVD 1988 (NAVD) Datum. Data in the NGVD 1929 (NGVD29) datum (e.g. some as-built records) and the City of Quincy Datum (e.g. GIS and most record plans) were converted using the following formulas:

1. NAVD88 = NGVD29 – 0.80 ft[1]
2. NAVD88 = Quincy Datum – 6.63 ft[2]

2.3 Ground Elevations

Ground elevations are used both for development of the 2D surface model, and for determining manhole rim elevations. Ground elevations for this model were based on LiDAR data collected post Hurricane Sandy (2013/2014) with a horizontal resolution of 1 meter (MassGIS 2016). **Figure 3** shows LiDAR for the modeled area. The accuracy of the elevation data provided in this dataset was confirmed through comparison with 1-foot contour data from the 2017 Quincy Flyover Dataset.

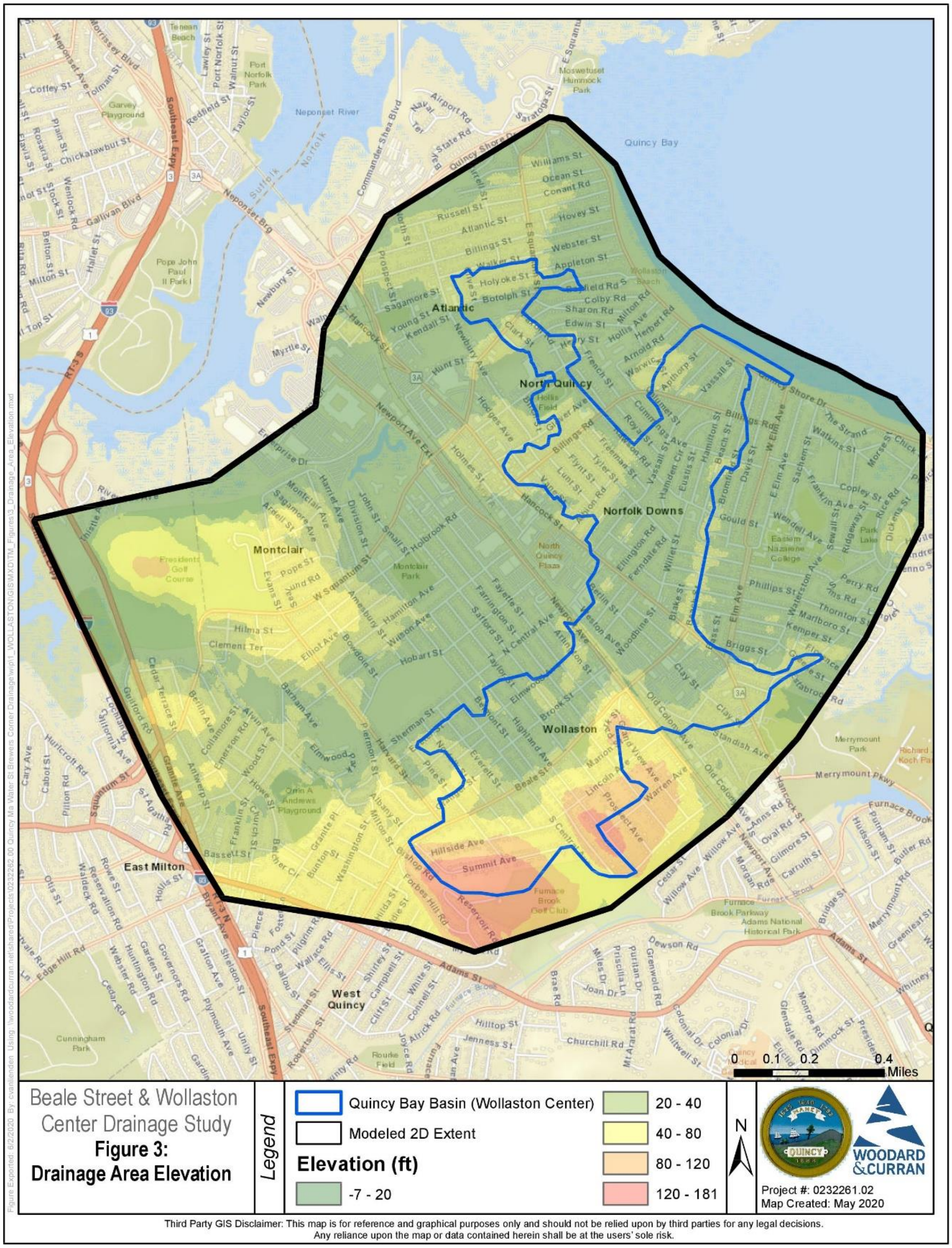
2.4 2D Surface Model Development

The drainage area for the 2D surface model was delineated in order to ensure that all drainage was captured that flows into the Beale Street & Wollaston Center focus area and discharges through outfall OF-00871, defined in **Figure 2** and its associated stormwater pipes.

[1] Source: NOAA conversion near Central Quincy (42.241° N, 71.01° W)

[2] Source: Massachusetts Highway Survey Manual Appendix A-2

Figure 3: Drainage Area Elevation



2.4.1 Mesh Development

The 2D surface model mesh was generated based on the ground elevation data discussed above. In general, element sizes were set between 100 and 1,075 square feet; terrain-sensitive meshing was included to allow for finer resolution in areas with sharper changes in elevation. A normal boundary condition was defined along the 2D mesh, which allows for water to flow freely across the mesh boundary.

2.4.1.1 Roads

Roads were represented in the ICM mesh using Mesh zones to better represent conveyance along the roads. Mesh zones allow for finer mesh resolution and deviations from ground elevation. Road centerlines were obtained from the 2017 Quincy Flyover Dataset. To represent roads in the 2D model, a 15-foot buffer on either side of the centerline was applied to represent the width of the road. Element sizes between 15 and 150 square feet were applied within the road width and elevation adjustment of -0.5 feet from the ground elevation was applied to represent the curb height. Note that while sidewalks are not included in this elevation adjustment, they are included in the impervious dataset for purposes of estimating roughness and infiltration, as described in sections 2.4.2 and 2.4.3, respectively.

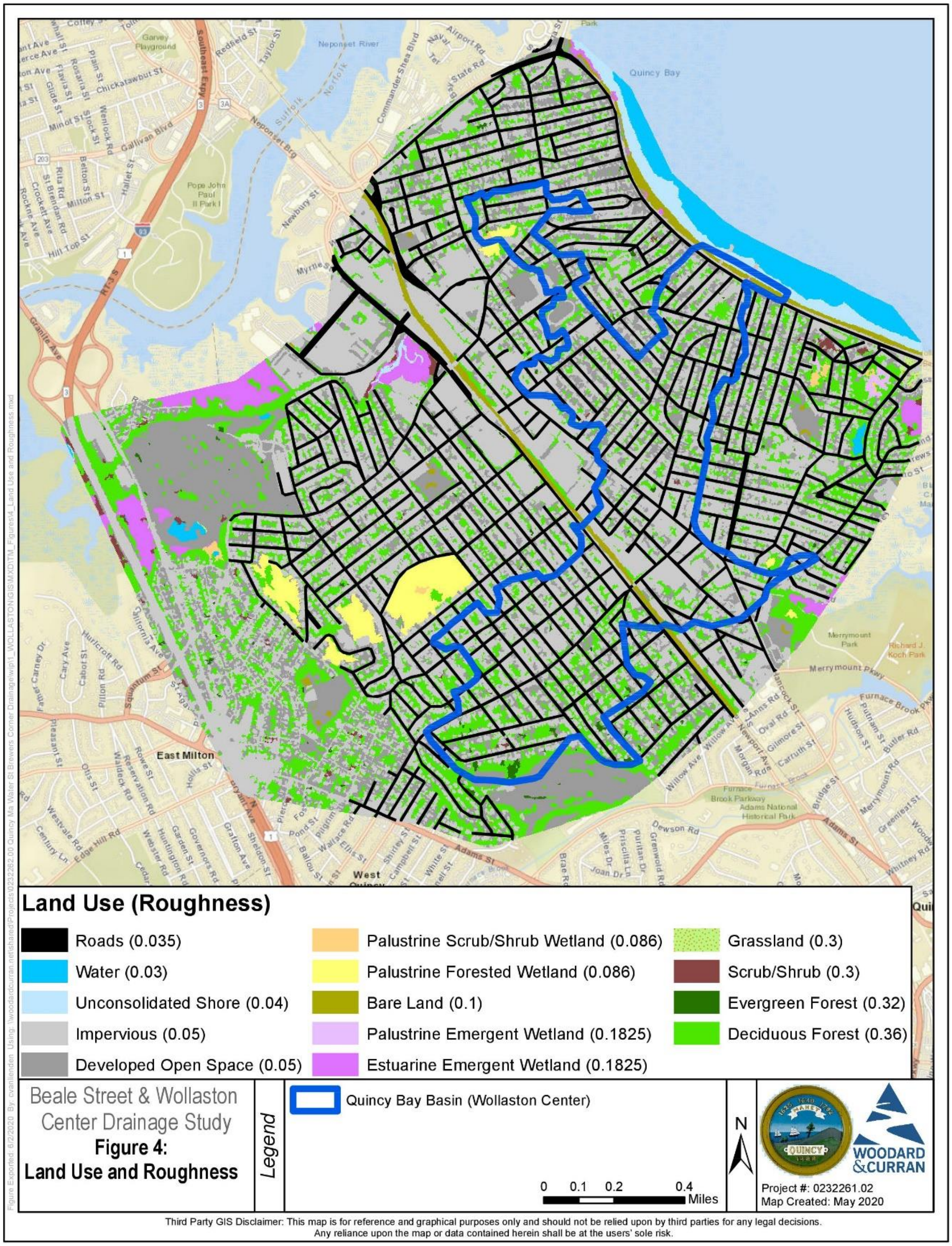
2.4.1.2 Buildings

Buildings obtained from the 2017 Quincy Flyover Dataset were represented in ICM as Mesh zones with element sizes between 50 and 300 square feet. An elevation adjustment of +0.5 feet from the ground elevation was applied to represent the doorstep. To limit conveyance through buildings, they were modeled as porous polygons with a porosity of 25%. This allows flow to occur across buildings once water levels reach +0.5 feet above ground elevation, but only at 25% of the normal rate. Building locations are shown in **Figure 5**.

2.4.2 Roughness (Manning's n)

Manning's roughness values represent how roughness or friction against flow varies across the drainage area. The Land Use (2016) data layer from the Massachusetts Bureau of Geographic Information (MassGIS) includes land use information across the modeled area that formed the basis for most of the roughness values. **Figure 4** shows the modeled area's land uses and their corresponding roughness values. Manning's roughness values for each land use were adapted from the Flo-2D (2017) Reference Manual, which includes compiled information on several historical studies of manning's roughness.

Figure 4: Land Use and Roughness



2.4.3 Infiltration

To represent infiltration, hydrologic soil groups were obtained from the USDA Soil Survey Geographic Database (SSURGO) for Massachusetts. Hydrologic soil group data exists for most of the modeled area; however, for areas without hydrologic soil groups defined, an average soil group was defined based on surrounding areas. Green-and-Ampt parameters were defined based on guidance from Rawls et al. (1982) and ICMs help manual that relate hydrologic soil groups to Green-and-Ampt parameters. **Table 2** summarizes the parameters defined for different hydrologic soil groups and their corresponding soil types. For design storms the soil was assumed to be 50% saturated, resulting in the soil moisture deficits shown in **Table 2**.

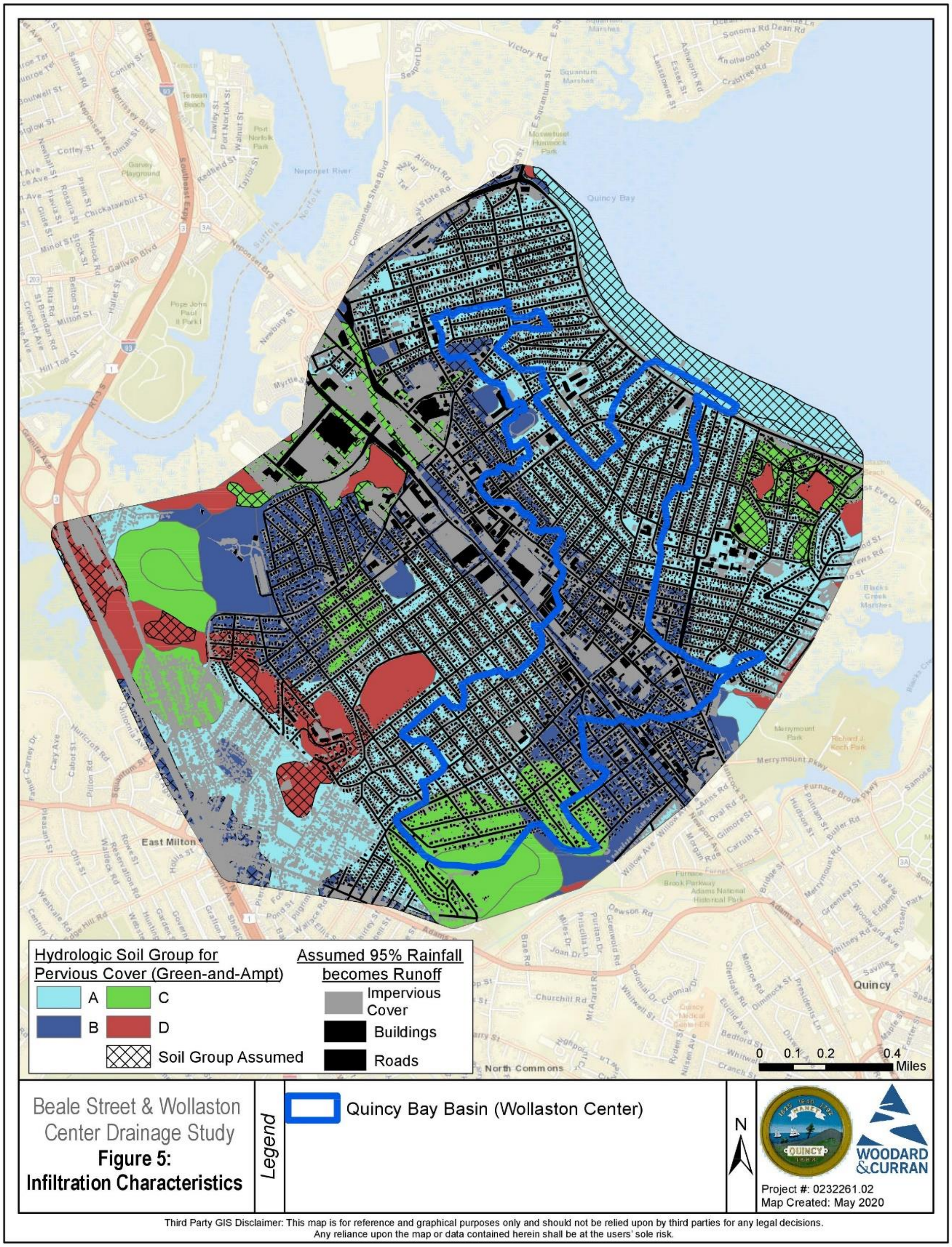
For impervious areas, 95% of rainfall was defined to become runoff using the Fixed Coefficient method in ICM. Impervious areas include roads, buildings, and other impervious areas (i.e. parking lots) defined by the land use layer of imperviousness from MassGIS (2016, MassGIS). **Figure 5** shows the different infiltration methods and parameters used. Infiltration was imported into ICM using Infiltration Zones and Infiltration Surfaces.

Table 2: Green-and-Ampt Parameters[1]

Hydrologic Soil Group	Porosity	Saturated Hydraulic Conductivity (in/hr)	Wetting Front Suction (in)	Initial Moisture Deficit (Assumed 50% saturated for design storms)	Soil Type
A	0.44	3.90	6.17	0.22	Sand to sandy loam
B	0.46	0.52	12.40	0.23	Loam
C	0.45	0.22	16.79	0.22	Silt loam to sandy clay loam
D	0.46	0.05	23.81	0.23	Clay loam to clay

[1] 1. Rawls et al. (1982) and ICM Help Manual used to define Green-and-Ampt parameters based on Hydrologic Soil Groups

Figure 5: Infiltration Characteristics



2.5 1D Stormwater Drainage Network Development

Sub-surface drainage facilities and concrete channels were added to the InfoWorks model as 1D components. The initial model network was constructed using GIS shapefiles from the 2017 Quincy Flyover Dataset, which included storm drain manholes and fittings, catch basins, pipes, and culverts. Most of the data included invert elevation data in the NAVD datum, as well as sizing information. After import, QA/QC procedures were performed to validate the data, including the following:

- **Connectivity checks**. The modeled network was checked for connectivity, which includes verifying that correct upstream/downstream manholes were identified for each pipe, with no missing links or nodes in the network. A connected network means that all pipes and manholes will be selected when the network is traced from downstream to upstream and vice-versa.
- **Missing data checks**. Key data required for modeling were reviewed to identify missing values. Missing data were inferred where reasonable (e.g., where one or two invert elevations were missing between populated values, the data could be interpolated). The remaining missing data were populated based on available record plans.
- **Profile review**. Profiles were plotted for each series of pipe segments in the modeled network to visually check for suspect data. Examples of suspect data include negative pipe slopes, abrupt steps up or down in pipe inverts, and pipe diameters that conflict with surrounding pipes. Where appropriate, suspect data were inferred or adjusted based on estimated datum difference, or available record plans.

Survey was not performed as part of this study. Where data were adjusted, flags were used in the model to document the adjustment and data sources.

A Manning's 'n' of 0.013 was assumed for the capacity evaluation of all existing drainage pipelines. The focus area does not have culverts or concrete drainage features. Connectivity to the 2D surface mesh occurs at all modeled manholes and catch basins; water is allowed to flow into and out of all storm drain manholes at the 2D surface mesh locations.

Figure 2 shows the modeled drainage network.

2.6 Downstream Boundary Condition (Quincy Bay)

The downstream end of the modeled watershed includes a tidal boundary conditions that is located along the downstream end of the modeled area across Quincy Bay, as shown in **Figure 6**. To define the tidal boundary condition tidal data were obtained at the closest tidal gauge to the focus area. The closest tidal gauge (ID 8443970) to the focus area is maintained by the National Oceanic and Atmospheric Administration (NOAA) and is located in Boston Harbor at the inlet to the Fort Point Channel (Lat: 42.3505, Long: -71.050). The extreme storm tide estimates shown in **Table 3** were obtained at this gauge based on observed data from 1921-Present. The Boston Harbor tidal gauge was considered a reliable source of information for extreme storm tide levels given its proximity to Quincy, given its similar tidal patterns to Town River Bay, and given the use of a Boston Harbor tidal gauge for the United States Army Corps of Engineers (USACE) 1985 study.

Figure 6: Tidal Boundary Location

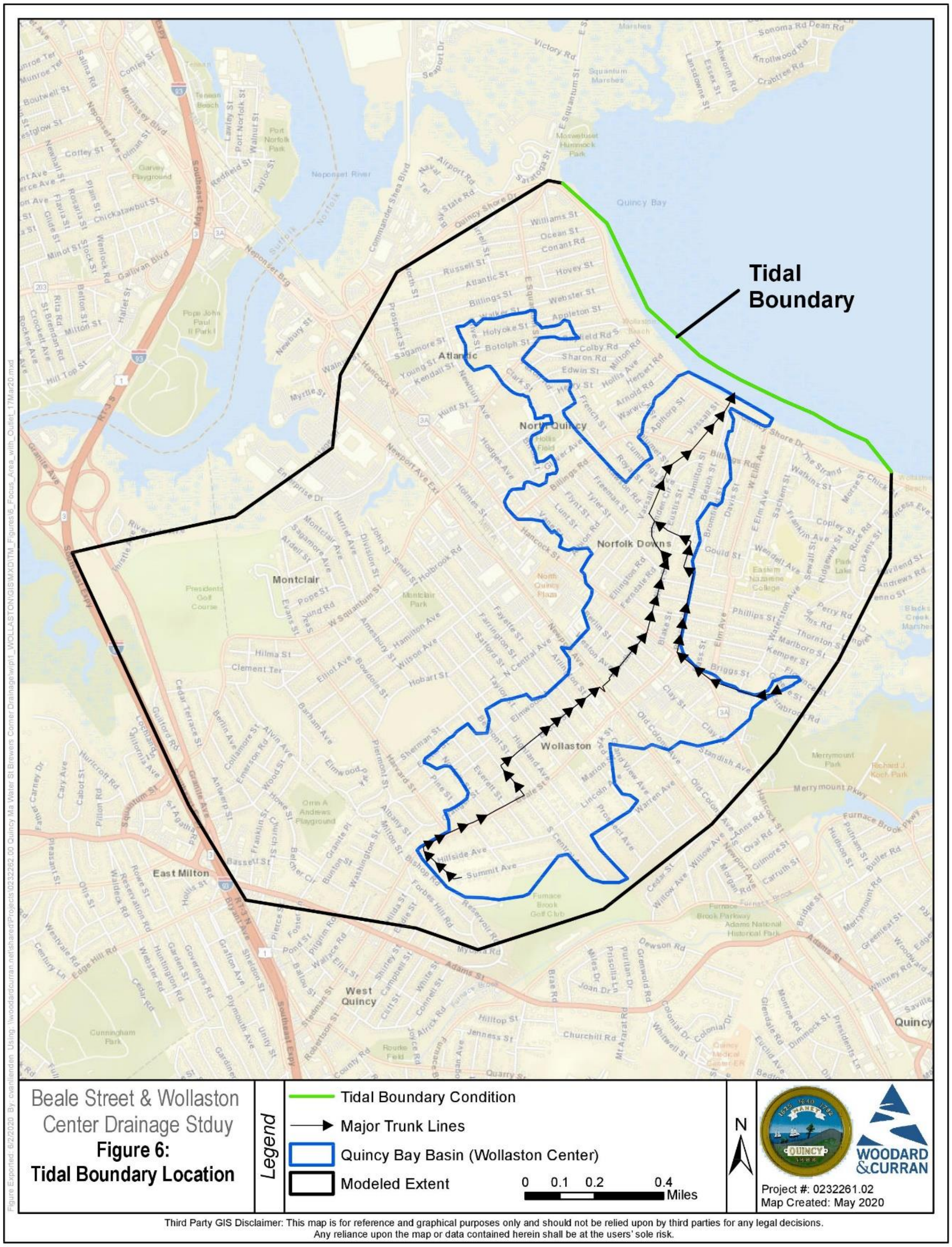
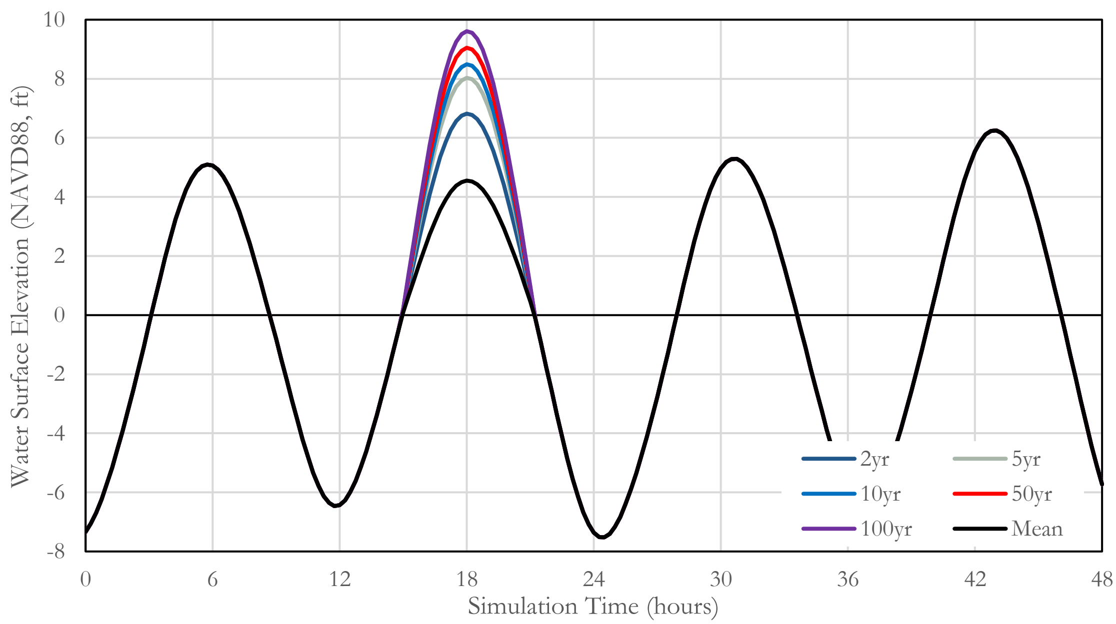


Table 3: Extreme Water Levels and Depths

Design Event	Mean	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Extreme Storm Tide Level (NAVD88, ft)	4.55	6.71	6.82	8.03	8.49	8.76	9.05	9.61

To define a time-variable boundary condition, representative of oscillating tidal conditions, the harmonic tidal predictions from NOAA at Town River Bay (ID 8444788) were obtained. The tidal predictions were collected for a typical 48-hour period in the month of January. As shown in **Figure 7**, the simulated tidal cycles start on low tide to mitigate model instabilities. As a result, the peak tide occurs 18-hours into the simulation. As discussed in the next section, the peak tide coincides with the design storm's peak rainfall intensity (approximately 30 minutes before peak runoff). For sensitivity purposes, model simulations have also been performed with the tide shifted 6 hours, so that peak rainfall intensity coincides with low tide conditions.

Figure 7: Tidal Boundary Condition



2.7 Design Rainfall Events

Design storms were developed for 1, 2, 5, 10, 25, 50, and 100-year 24-hour precipitation. The 24-hour rainfall depths and hyetographs were derived from the Northeast Regional Climate Center (NRCC), Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada (Cornell Atlas), by Cornell University. The Cornell Atlas uses local rainfall patterns based on interpolated station data to distribute the timing/intensity of design storms for New York and New England, rather than using traditional distribution curves (i.e. Type 1, 1A, II, and III) which average data from a large number of stations. **Table 4** shows the total rainfall for the different design events, **Figure 8** shows an intensity-duration-frequency plot, and **Figure 9** shows the 25-yr rainfall events rainfall intensity as an example. Note, the simulated rainfall was shifted so that peak rainfall would occur 18 hours into the simulation period as shown in **Figure 9**, to coincide with the mean high tide discussed in the previous section.

Table 4: Total Rainfall for Design Events

Design Event	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Total Rainfall (in)	2.72	3.28	4.12	4.9	6.16	7.32	8.71

Figure 8: Design Storm Intensity-Duration-Frequency

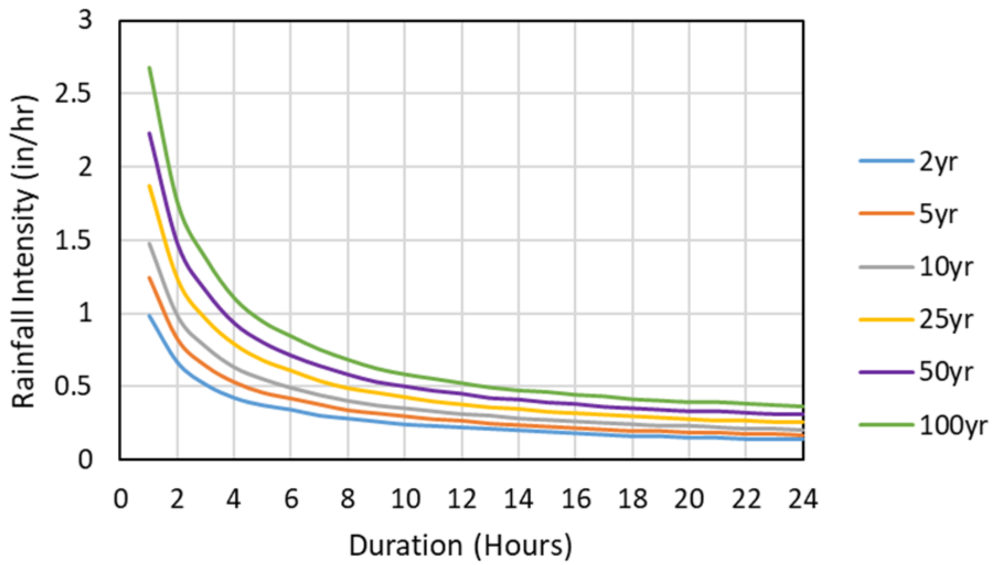
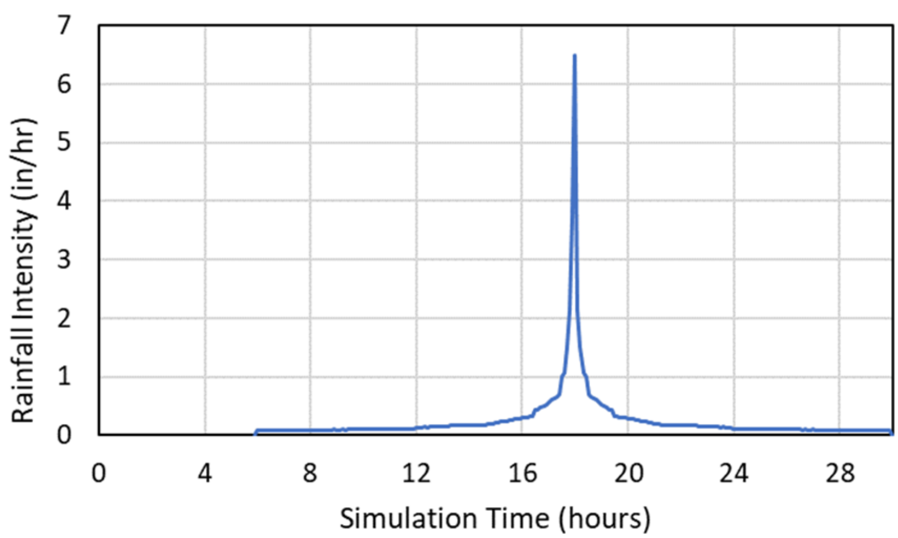


Figure 9: 25-yr Design Rainfall Event



2.8 Historical Storm Validation

Validation of the model was conducted utilizing several sources. The Wollaston Center subbasin does not have any streamflow or stage gauges to validate against. In the absence of this data, phone calls of flooding instances reported to the City of Quincy's Emergency phone call log were collected and used to validate the model results. The phone calls included a description of the flooding and an address associated with the flooding issue(s). All calls reported that flooding occurred for frequent rainfall events, likely indicating that a 1-yr return period (i.e. 2.7 inches of cumulative rainfall) flood event would result in flooding associated with the reported locations.

Figure 10 demonstrates that the developed model for the Wollaston Center subbasin captures flooding associated with the emergency phone call log from the City of Quincy for events as small as the 1-yr flood event. The model was also validated against FEMAs 100-yr floodplain. As shown in **Figure 11**, the model results compare well to FEMAs floodplain. However, FEMA has not included stormwater drainage infrastructure in their analysis of coastal floodplains. This explains why FEMA likely does not capture some of the flooding observed from the model results in the upstream reaches of the stormwater drainage network above the tidal influence of Quincy Bay.

Based on validation against emergency flood-related phone calls and a comparison against FEMAs 100-yr floodplain, the model is considered reliable for representing existing flooding issues throughout the Wollaston Center subbasin.

Figure 10: Flood Predictions & Emergency Call Locations

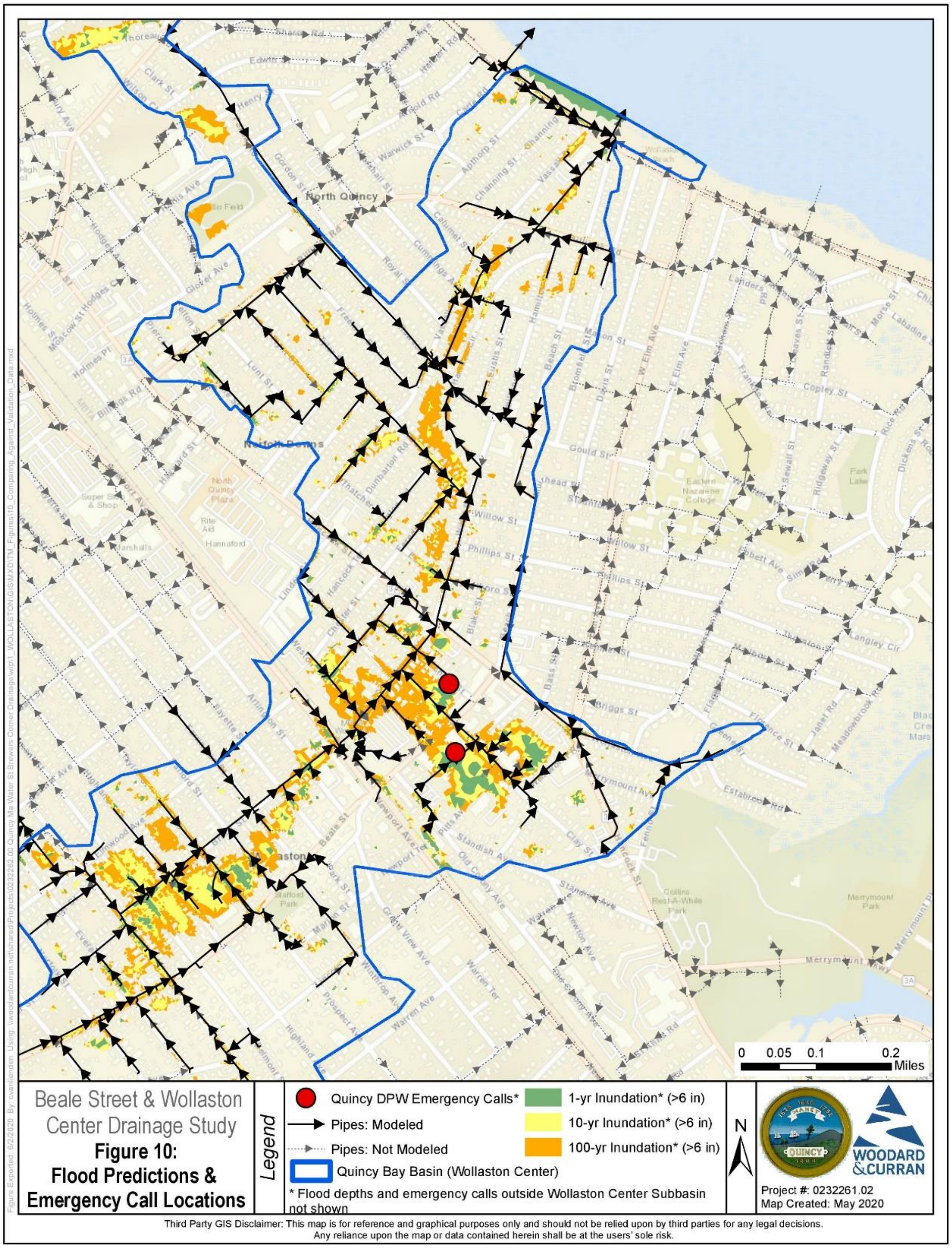
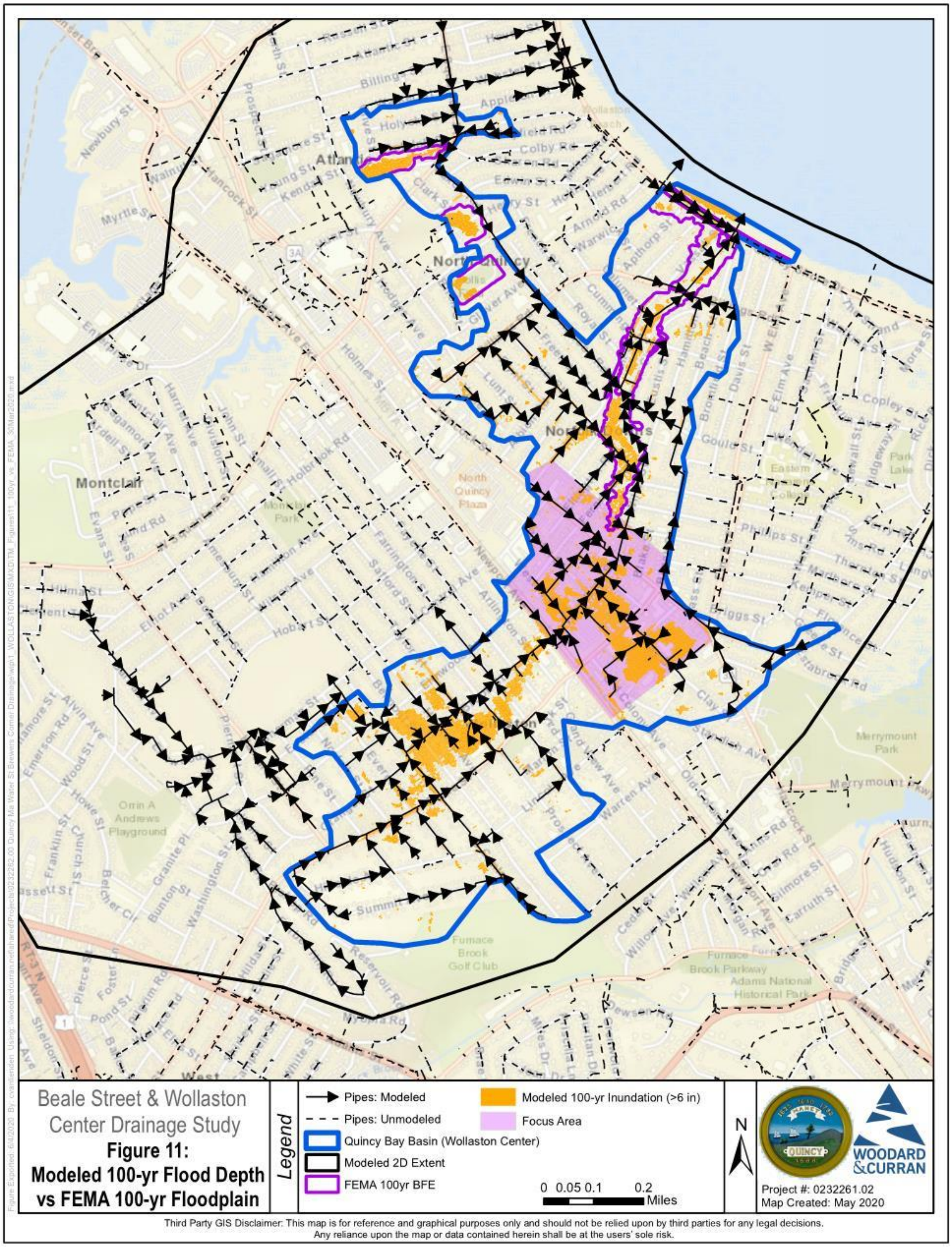


Figure 11: Modeled 100-yr vs FEMA



3. MODEL RESULTS FOR DESIGN STORMS

Figure 12 depicts the 100-yr water depth throughout the modeled area. This figure also highlights locations of interest where flood depths are reported in **Table 5** for the suite of return period events simulated. Hydraulic grade lines under various storm and tidal conditions for the trunk storm drain, as well as for the 18- and 12-inch drainage line through the focus area (on Chapman Street and south to Old Colony Avenue), are included in Appendix A and Appendix B, respectively.

Table 5: Modeled Peak Flows and Depths at Selected Locations

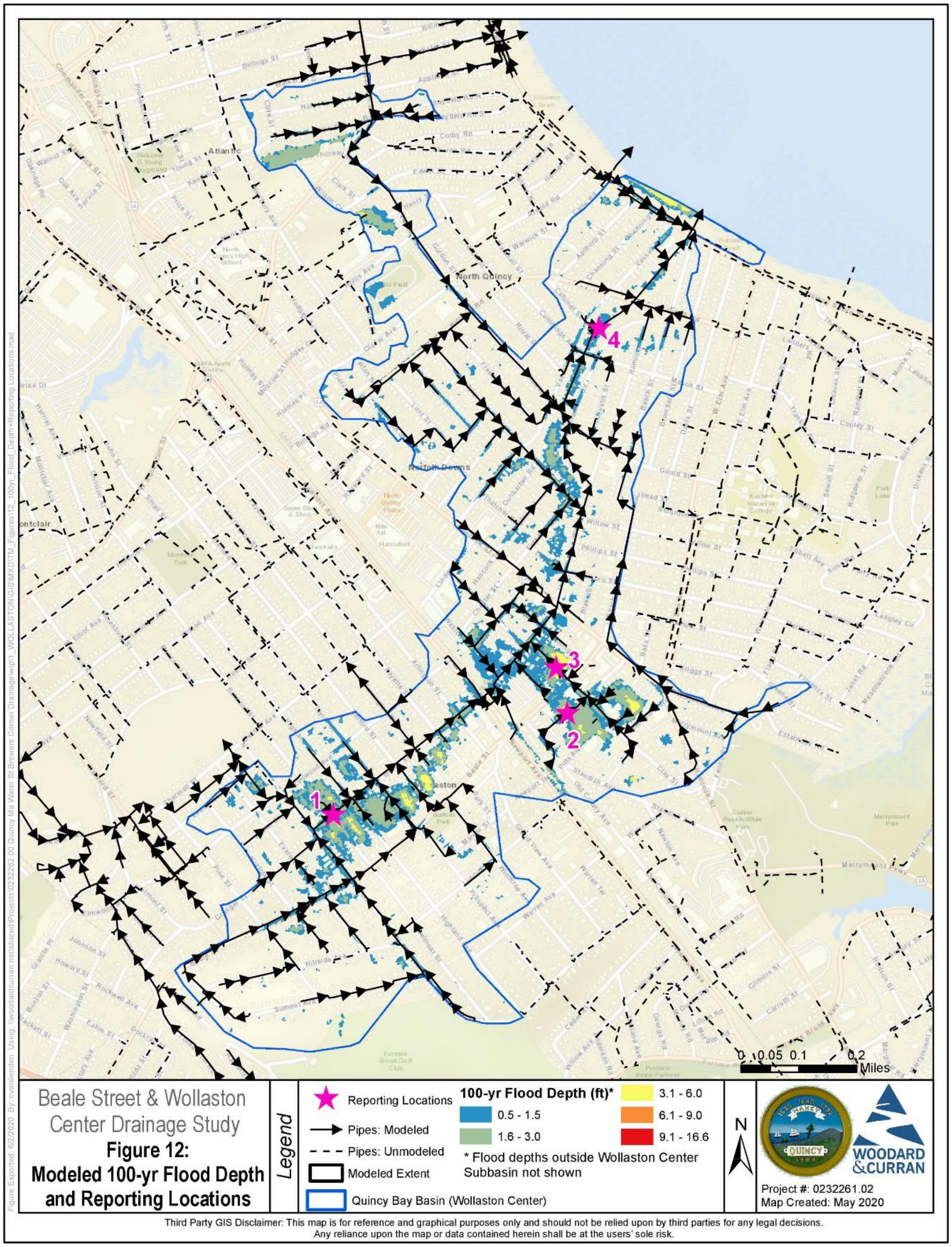
Return Period	Location 1 DMH-03056 (Belmont and Brook St.)	Location 2 CB-02637 (Upstream of Chapman and Beale St.)	Location 3 CB-02440 (Downstream of Chapman and Beale St.)	Location 4 DMH-01108 (Near Vassal and Cummings Ave.)
	Ground Level (NAVD88,ft)			
	15.9	11.4	11.9	7.9
	Flood Depth (ft)			
2-yr	1.1	4.4	1.2	0.0
5-yr	1.4	4.9	1.9	0.7
10-yr	1.7	5.1	2.6	0.9
25-yr	2.2	5.1	3.3	1.3
50-yr	2.6	5.6	3.7	1.7
100-yr	2.9	6.1	4.1	2.4

Notes:
a. Ground level corresponds to rim elevation of drain manholes at each location.

Model results indicate that flooding occurs in the focus area under all modeled storm events and under all tidal conditions. Under low tide conditions, the storm drains upstream of Hamden Circle & Rawson Road are undersized for the design storm runoff, resulting in flooding. Under high tide and surge tide conditions, downstream elevated water levels further limit the ability of the storm drains to drain effectively.

Because the trunk storm drain is surcharged significantly during the design storm events, the smaller drainage lines within the focus area are unable to effectively drain. As a result, the model of existing conditions cannot determine the adequacy of the existing drainage lines through this area; if improvements are implemented to conveyance in the trunk system, flooding could still occur due to insufficient capacity in the smaller lines. Further analysis of the system, including development of solutions for trunk conveyance, are needed to assess the drainage capacity of the upstream drainage network.

Figure 12: Modeled 100-yr Flood Depth and Reporting Locations



4. CONCLUSION

As detailed above, this study has successfully modeled the existing drainage system of the Beale Street & Wollaston Center focus area, listed as a priority area in the City's 2019 Drainage Capital Plan. This report will serve as the basis for future planning and alternatives studies to reduce the frequency, duration, and extents of flooding in the Beale Street & Wollaston Center neighborhood.

This report has identified potential causes for flooding observed in the roadways and adjacent public and private properties of the Beale Street & Wollaston Center focus area. The model results generally indicates that flooding in the focus area is caused by both insufficient drainage capacity in the drainage trunk upstream of Hamden Circle and Rawson Road, as well as high water levels during high tide and surge tide conditions.

The next phase of this project will be to analyze potential infrastructure improvement alternatives to mitigate the hydraulic deficiencies identified within the Focus Area in this report. The future alternatives analysis will lead to implementing feasible drainage system modifications to address existing flooding conditions and inadequate capacity of the municipal drainage system, and ultimately facilitate redevelopment of the Beale Street & Wollaston Center neighborhood.

APPENDIX A: HYDRAULIC PROFILES OF THE DRAINAGE TRUNK UNDER VARIOUS CONDITIONS

Figure A-1: Main Trunk 2-yr Hydraulic Grade Line: Belmont and Brook St. to Quincy Bay

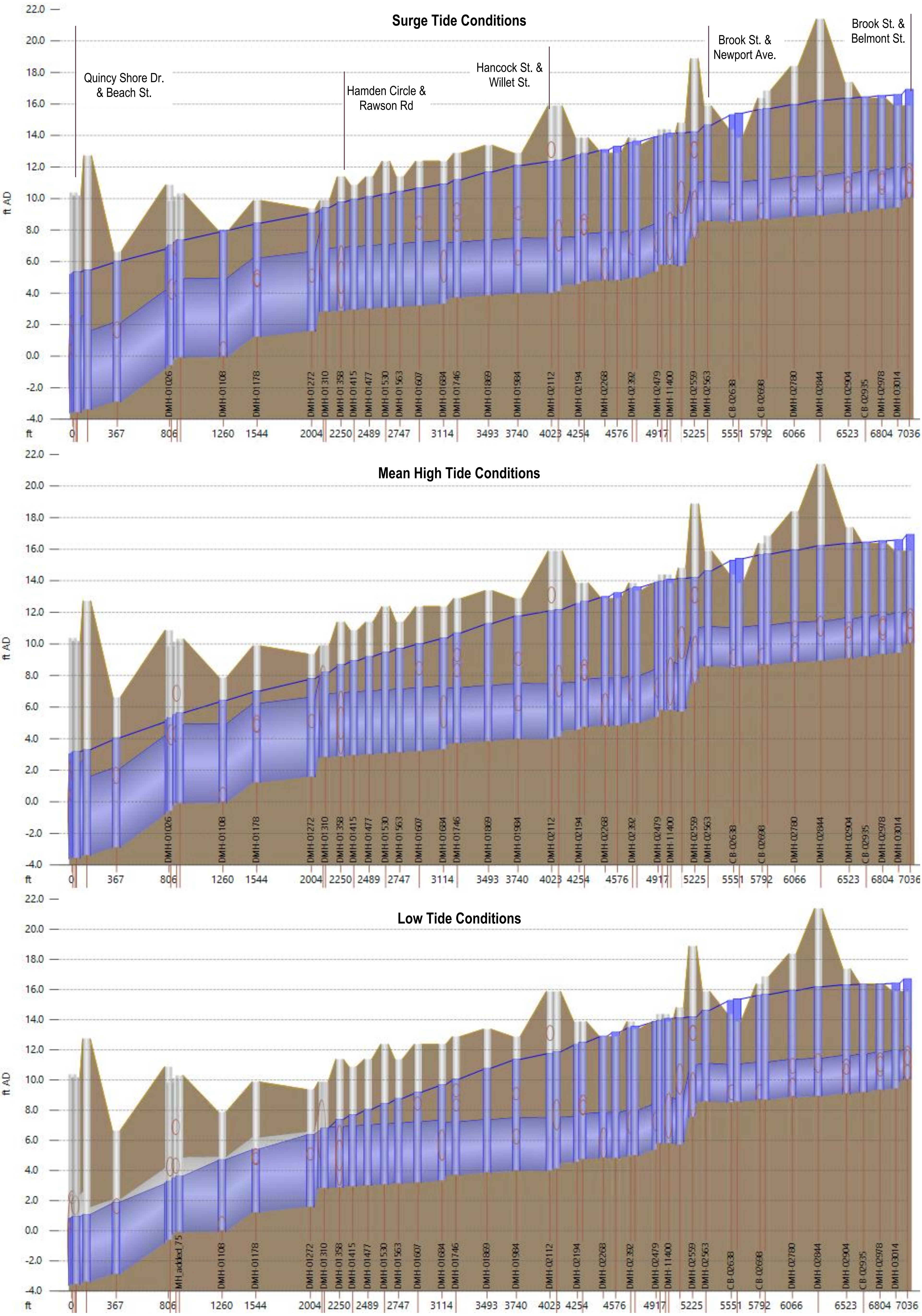


Figure A-2: Main Trunk 5-yr Hydraulic Grade Line: Belmont and Brook St. to Quincy Bay

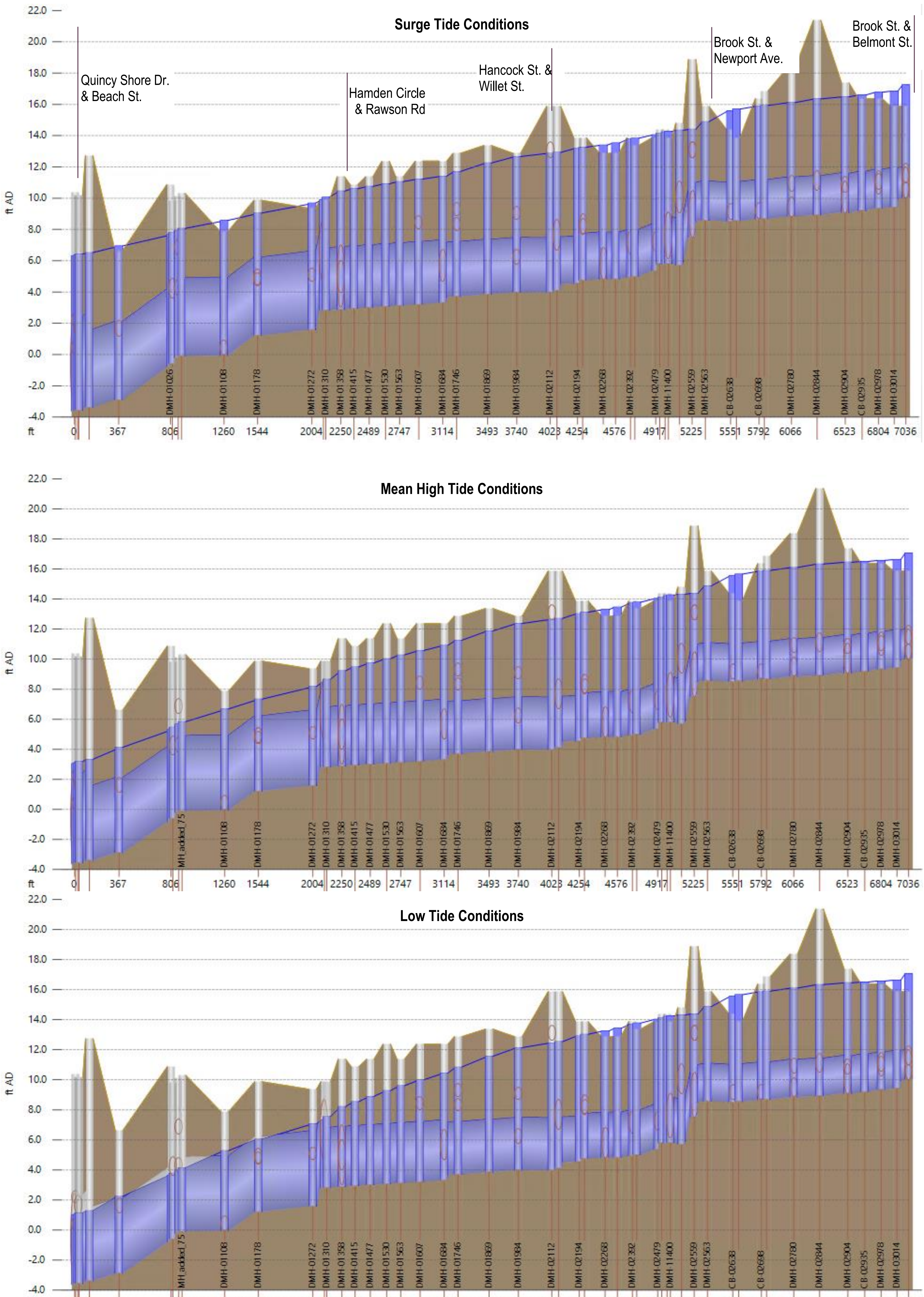


Figure A-3: Main Trunk 10-yr Hydraulic Grade Line: Belmont and Brook St. to Quincy Bay

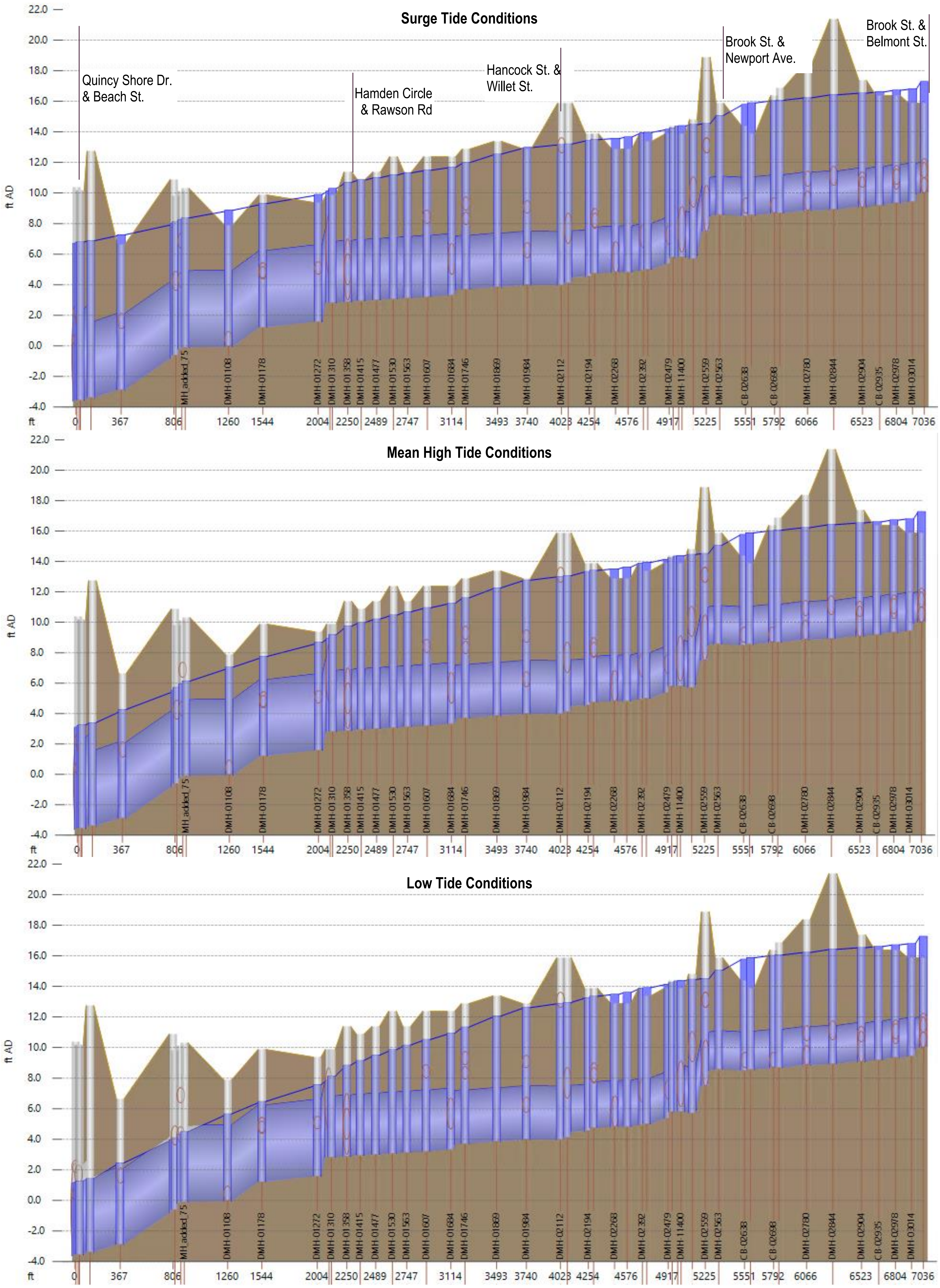


Figure A-4: Main Trunk 25-yr Hydraulic Grade Line: Belmont and Brook St. to Quincy Bay

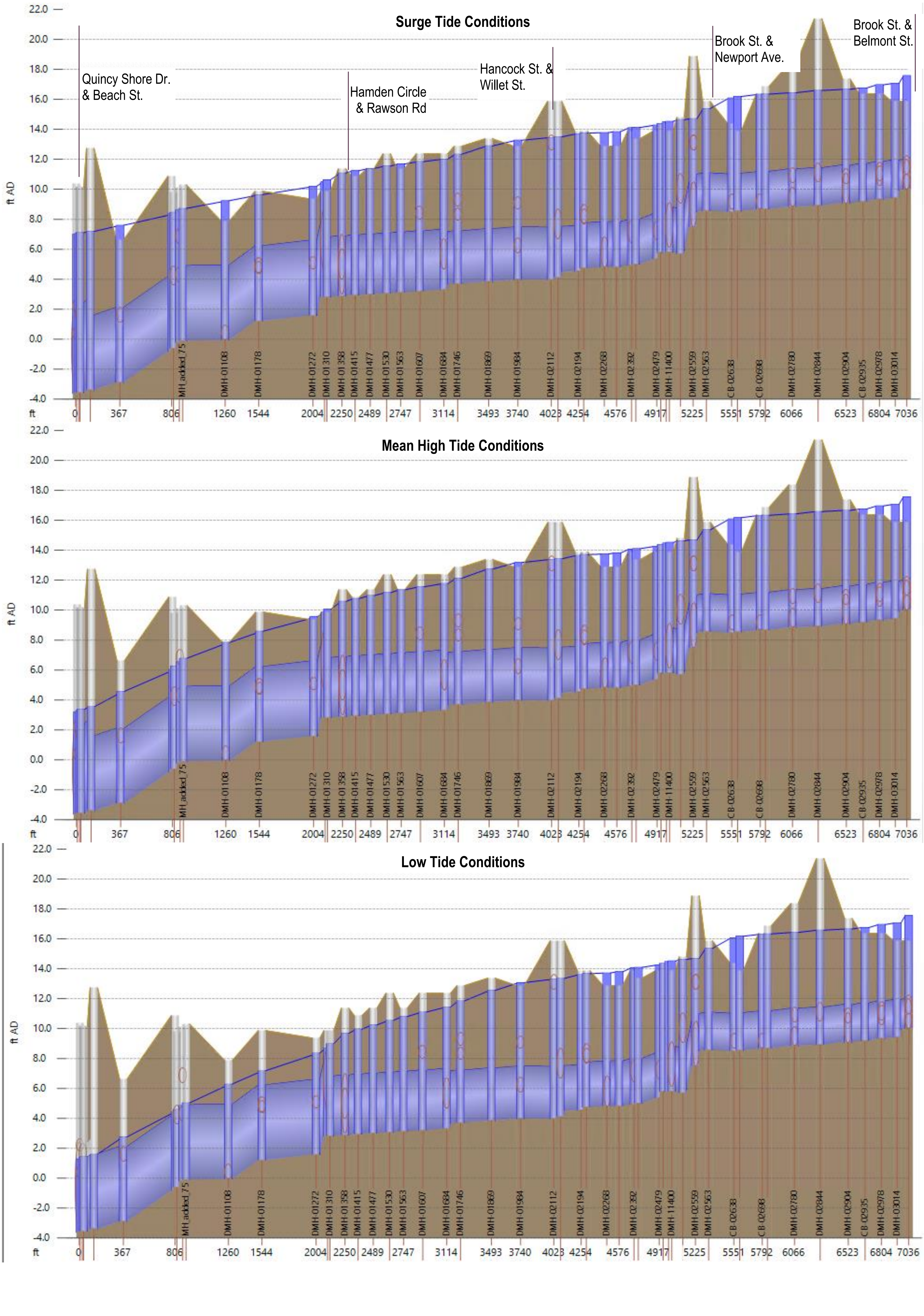


Figure A-5: Main Trunk 50-yr Hydraulic Grade Line: Belmont and Brook St. to Quincy Bay

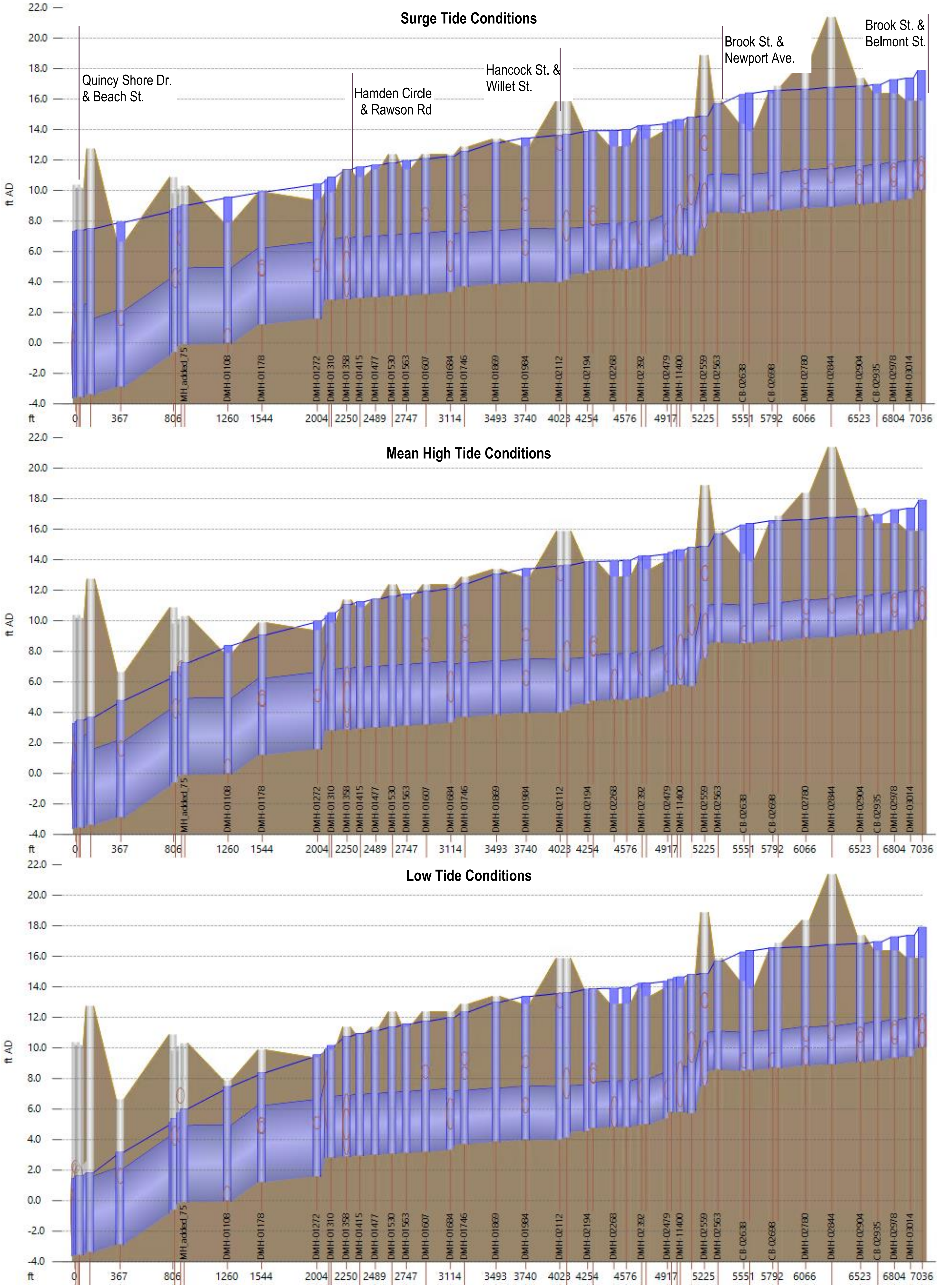
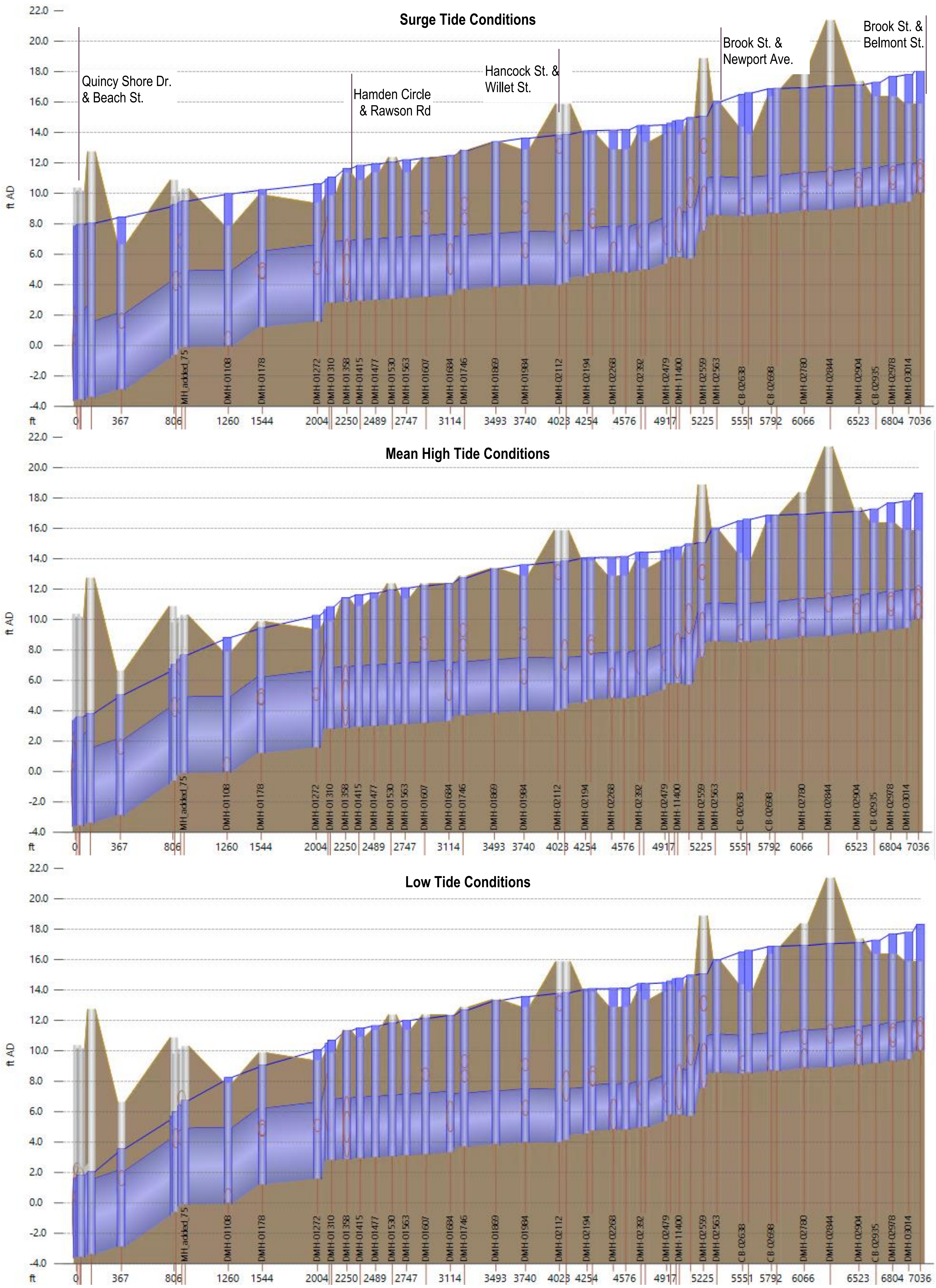


Figure A-6: Main Trunk 100-yr Hydraulic Grade Line: Belmont and Brook St. to Quincy Bay



APPENDIX B: HYDRAULIC PROFILE OF DRAINAGE LINE THROUGH THE FOCUS AREA UNDER VARIOUS CONDITIONS

Figure B-1: Drainage Line 100-yr Surge Tide Hydraulic Grade Line: Old Colony Ave s/o Beale St. and Brook St. to Chapman and Woodbine St.

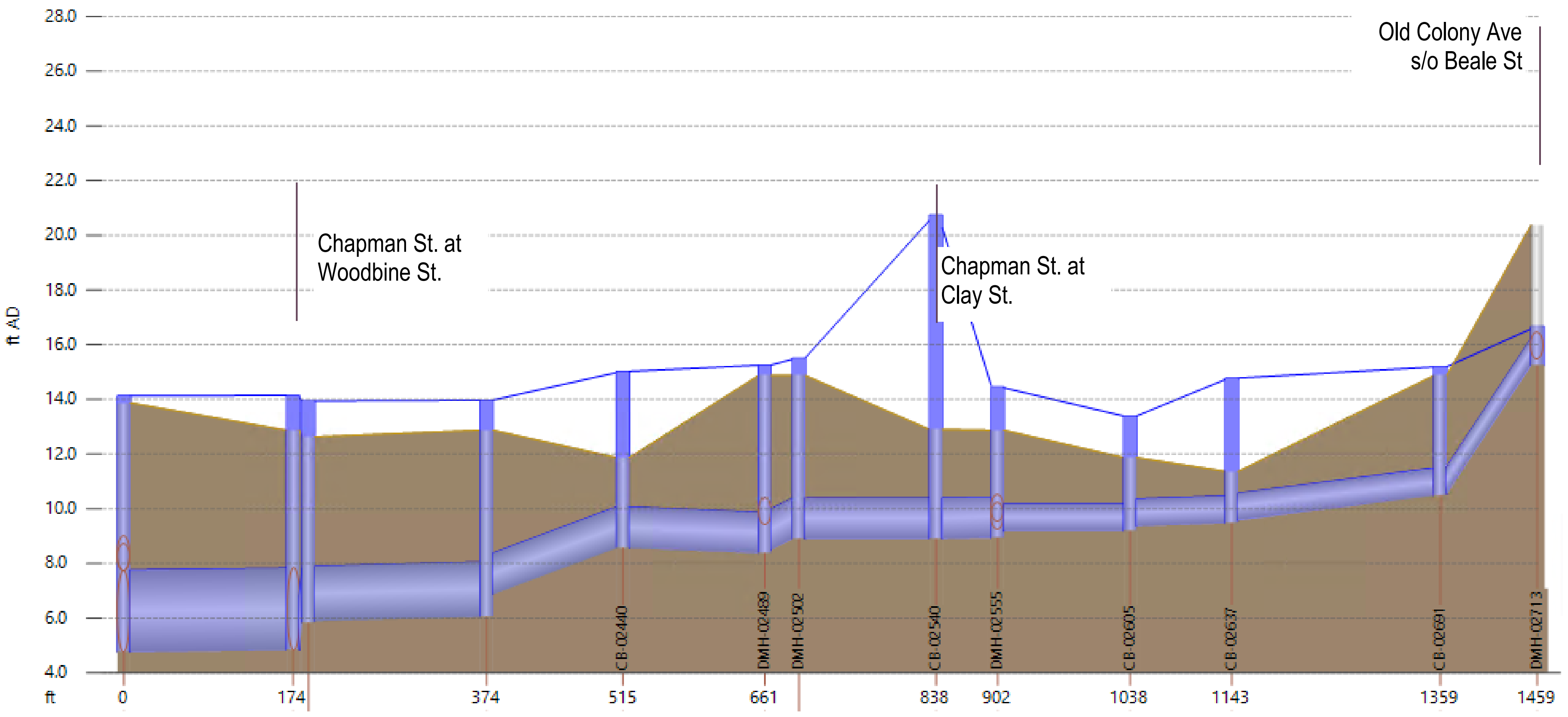


Figure B-2: Drainage Line 10-yr Mean High Tide Hydraulic Grade Line: Old Colony Ave s/o Beale St. and Brook St. to Chapman and Woodbine St.

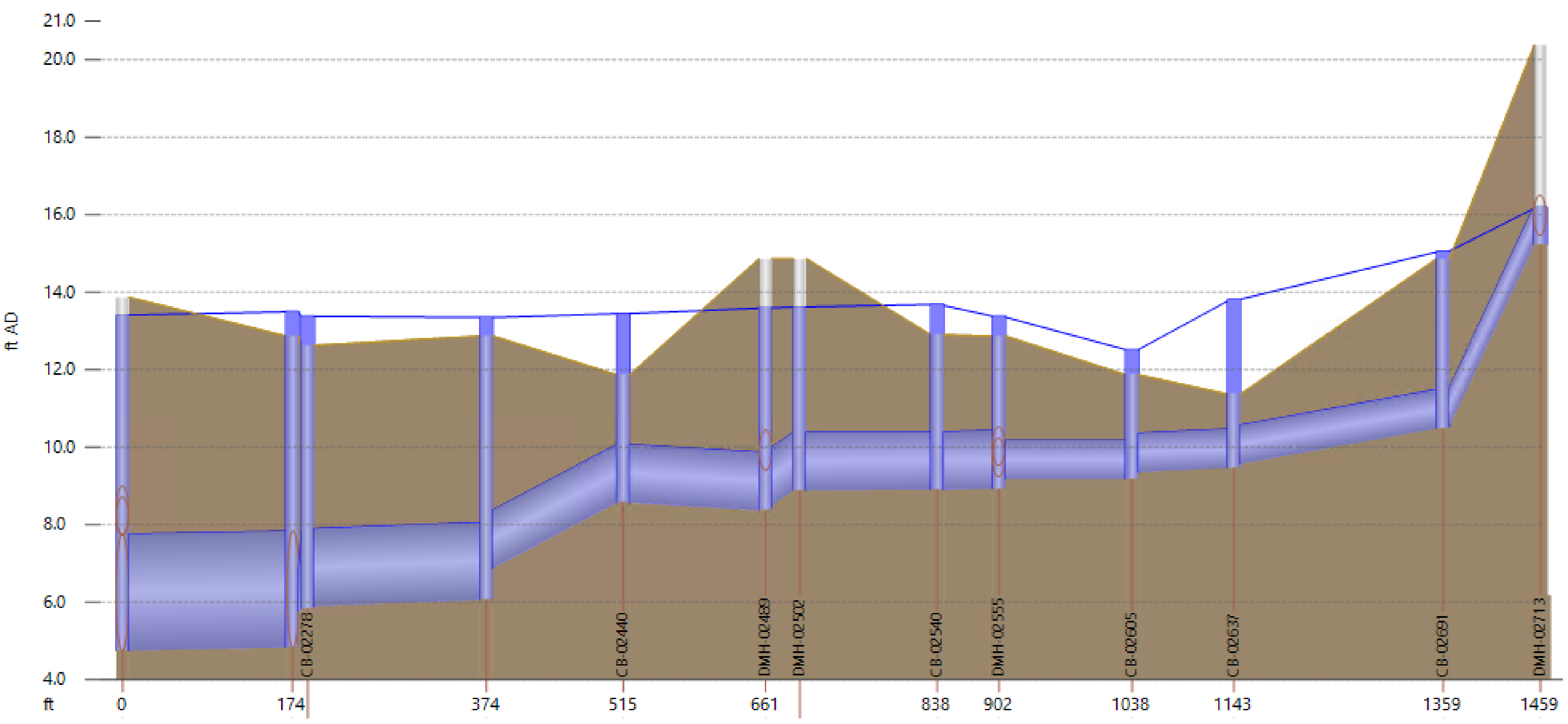
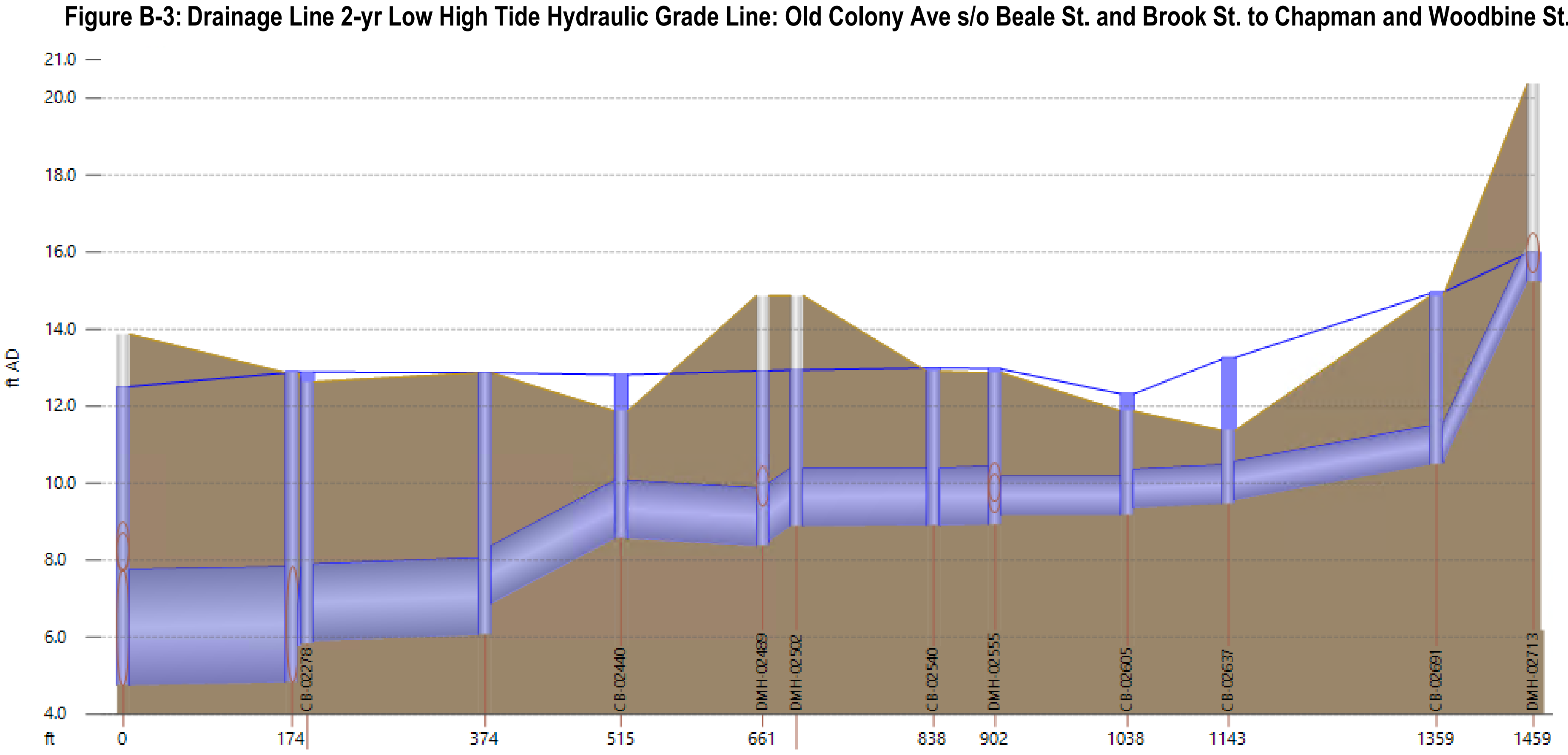


Figure B-3: Drainage Line 2-yr Low High Tide Hydraulic Grade Line: Old Colony Ave s/o Beale St. and Brook St. to Chapman and Woodbine St.



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